SPECIFICATION

To All Whom It May Concern:

Be It Known That I, Xiaolan Ai, a citizen of the United States of America residing in the City of Massillon, County of Stark, and State of Ohio, whose post office address is 4480 Noble Loon Street, N.W., Massillon, Ohio, 44646, petition that Letters Patent of the United States of America be granted for my invention of a new and useful improvement in a:

TWO SPEED TRANSMISSION WITH SMOOTH POWER SHIFT

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is related to United States Provisional Patent Application 60/464,312 filed April 21, 2003 from which priority to such application is claimed.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable.

BACKGROUND OF THE INVENTION

Current rotorcraft (helicopter) transmission systems are designed for a single reduction ratio with the engine optimized at a single rotational speed. These transmission systems have no ability to vary the rotor speed other than changing the engine speed. In fact, recent studies have indicated that changing rotor speed using a transmission can provide significant benefits. A 15% rotor speed reduction can result in as much as 5dB noise-reduction. In contrast, changing the rotor speed by varying the engine speed may have adverse consequences. For example, varying the engine speed impairs engine fuel efficiency and could force the engine to operate closer to the critical stall boundary speed.

Rotorcrafts and/or tilt wing crafts have two modes of operation: a hover mode and a high-speed forward flight mode. In hover mode, a high rotor speed is desirable to improve maneuverability and load factor. In the high-speed forward flight mode, a reduced rotor speed will significantly reduce the rotor noise and keep the velocity of advancing blades subsonic. Thus, in light of the above, a two-speed transmission is needed.

Various transmission concepts have been considered. These transmissions fall generally into two broad categories: those that are continuously variable transmissions (CVT) and those that are two-speed transmissions. Most CVT's were based on traction

drives or friction drives where the power was transferred though non-positive engagement frictional contacts. These drives are relatively large and heavy, and their efficiency is poor. Additionally, reliability is a major concern for this type of drive.

Two-speed transmissions that generally using gears to transmit torque and power have a higher power-density and are more efficient than CVT's. However, shifting from one speed to another speed has proven to be a challenging task -- particularly under high power. The shift is usually abrupt and large power changes take place abruptly within the transmission. Either of these characteristics could cause a momentary loss of output power or damage to the transmission or drive train.

SUMMARY OF THE INVENTION

The current invention relates to variable speed transmissions in general and more specifically to a two-speed transmission with a smooth powered shift. Additional features of the present invention will be in part apparent and in part pointed out hereinafter.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

In the drawings, wherein like numerals and letters refer to like parts wherever they occur.

FIG. 1 is a vertical section view of one embodiment of the present invention; and

FIG. 2 is a general schematic of one embodiment of the present invention;

Corresponding reference characters indicate corresponding parts throughout the several views of the drawings.

While one embodiment of the present invention is illustrated in the above referenced drawings and in the following description, it is understood that the embodiment

shown is merely for purpose of illustration and that various changes in construction may be resorted to in the course of manufacture in order that the present invention may be utilized to the best advantage according to circumstances which may arise, without in any way departing from the spirit and intention of the present invention, which is to be limited only in accordance with the claims contained herein.

DETAILED DESCRIPTION

Description of the Apparatus and Method

Referring to Figures 1 and 2, a two speed transmission A is shown as one embodiment of the present invention. The two speed transmission A is comprised of a compound planetary train 1 having a first planetary unit U1 and a second planetary unit U2, a first electric machine 3, a second electric machine 4, a first locking device 5, and second locking device 6.

The first planetary unit U1 comprises a first sun gear 7 that is operatively connected to an input shaft 8 which is rotated by an engine (not shown), a first set of planetary gears 9, and a first ring gear 10. The first ring gear 10 has a first bull gear 11 that can be selectively connected to a first fixed member 27 in the two speed transmission A and that can be held stationary by activating the first locking device 5.

The second planetary unit U2 comprises a second set of planetary gears 12 and a second ring gear 13. Like the first ring gear 10 in the first planetary unit U1, the second ring gear 13 is integrated with a second bull gear 14 that can be selectively connected to a second fixed member 15 in the two speed transmission A and that can be held stationary by activating the second locking device 6.

The first set of planetary gears 9 in the first planetary unit U1 is compounded with the second set of planetary gears 12 in the second planetary unit U2 to form a planetary cluster 16. The planetary cluster 16 is supported on a common carrier 17 which is operatively connected to an output shaft 18 that drives a lift rotor or propeller through reduction gear trains (not shown).

The first electric machine 3 comprises a first rotor 19 and a first stator 20. The first rotor 19 is connected to a shaft 21 which in turn is connected to a first pinion gear 22 at its end. The first pinion gear 22 meshes with the first bull gear 11.

The second electric machine 4 comprises a second rotor 23 and a second stator 24. The second rotor 23 is connected to a shaft 25 which in turn is connected to a second pinion gear 26 at its end. The second pinion gear 26 engages the second bull gear 14.

The two electric machines 3 and 4 are electronically connected to each other to supply or receive power to or from each other through a power control and converting unit (not shown). Each electric machine 3 and 4 may also be connected through the power control and converting unit to external power sources (not shown).

Detailed Description of the Operation

In the present embodiment, the two speed transmission A operates primarily in two modes. The first mode results in a rotating speed ratio R_1 between the input shaft 8 and the output shaft 18. The second mode results in a rotating speed ratio R_2 between the input shaft 8 and the output shaft 18. It will be appreciated that in either mode of operation in the present embodiment, there is only one mechanical path for power transmission from the input shaft to the output shaft.

In the first mode, the first ring gear 10 is grounded by engaging the first locking device 5, fixing it to a first stationary member 27 of the two speed transmission A. The second locking device 6 is disengaged, leaving the second ring gear 13 free-wheeling with the second bull gear 14. The input power received from the input shaft 8 goes through the first sun gear 7, to the first set of planetary gears 9 of the planetary cluster 16, to the common carrier 17, and then is delivered to the output shaft 18. The power is transmitted from the input shaft 8 to the output shaft 18 at the first speed ratio R_1.

In the second mode, the second locking device 6 is engaged, grounding the second ring gear 13 together with the second bull gear 14 to the second stationary member 15. The first locking device 5 is disengaged, freeing the first ring gear 10 and the first bull gear 11. The input power is received from the input shaft 8 and goes through the first sun gear 7, and through both sets of planetary gears 9 and 12 of the planetary cluster 16, to the common carrier 17, and then is delivered to the output shaft 18. The power is transmitted from the input shaft 8 to the output shaft 18 at the second speed ratio R_2.

In the first mode of operation, as the first ring gear 10 is grounded to the first fixed member 27, it provides a reaction torque to balance the differential torque between the input 8 and the output shaft 18 that are rotating at the first rotating speed ratio R_1. In the second mode of operation, the second ring gear 13 is grounded and provides a reaction torque to balance the differential torque between the input shaft 8 and the output shaft 18 that rotate at the second rotating speed ratio R_2. It is understood that in the present embodiment, the reaction torque in the two operation modes is in the same direction.

To shift from the first mode to the second mode, the first locking device 5 is released. Upon such release, a command is sent to the second electric machine 4 to

provide a reaction torque to retard the rotation of the second ring gear 13. In doing so, the second electric machine 4 converts mechanical power into electrical power.

The electric power generated during the shift from the first mode to the second mode is fed through the power control and converting unit (not shown) to power the first electric machine 3 to thereby share the reaction torque which otherwise is taken solely by the second electric machine 4. The first electric machine 3 thus drives and accelerates the first bull gear 11 along with the first ring gear 10. It is understood that the first ring gear 10 rotates in an opposite direction from the rotation of the second ring gear 13. As the speed of the first electric machine 3 increases, the speed of the second electric machine 4 decreases, and the share of reaction torque shifts toward the second electric machine 4. This trend continues until the second electric machine 4 comes to a stop and reaction torque is solely taken by the second electric machine 4. This completes the shift of the two speed transmission A and the second locking device 15 is then engaged, fixing the second ring gear 13 to ground and lifting the reaction torque off the second electric machine 4. In general, shifting from the second mode into the first mode is executed by a similar process, with the exception that the above process is generally reversed.

As one can appreciate, the shift between the first mode and the second mode is substantially continuous and smooth. Additionally, the transition between the two modes is accomplished under full transmission power and with no power interruption. This substantially continuous and smooth power shift occurs because the present embodiment of the invention provides two paths for power transmission from the input shaft 8 to the output shaft 18. One is a mechanical path, the other is an electrical path and because of an operational overlap between the mechanical path and the electrical path, power

variation in the mechanical path during the shifting is fully compensated by the electrical path, thereby resulting in smooth shifting between the modes. It is noted that the power transmitted through the electric path is usually a fraction of the total power.

The maximum power rating of the first and second electric machines 3 and 4 is determined by a number of factors. The most influential factor is the speed differential between the first rotating speed ratio R_1 and the second rotating speed ratio R_2. For rotorcraft, the desired differential between R_1 and R_2 is about 1.2. Therefore, the maximum power ratio for the first and second electric machines 3 and 4 is only about 5% of the maximum transmission power rating.

As can be appreciated, during normal mode of operation, one of the electric machines 3 or 4 is idling. Thus, in this or other embodiments of the present invention, the idling electric machine can be used as generator to generate electric power for onboard electronic accessories.

While the above description describes various embodiments of the present invention, it will be clear that the present invention may be otherwise easily adapted to fit any configuration where a two speed transmission with a smooth power shift is required. As various changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.